PART IIB 2010

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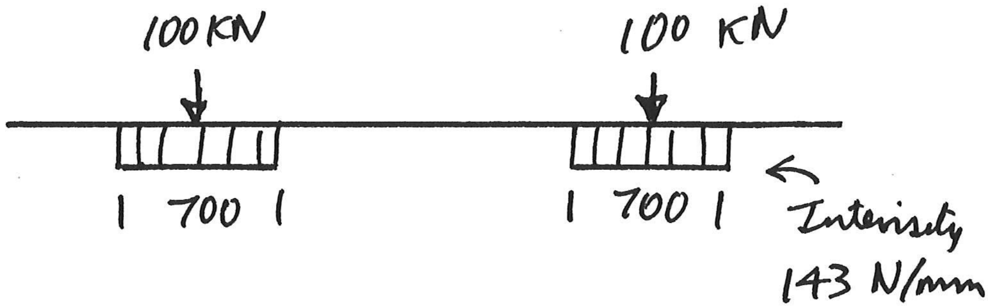
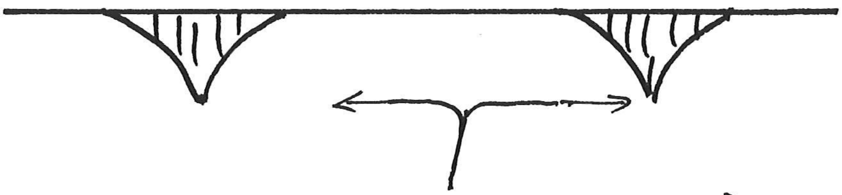
4D8 Exam 2010
Prestressed Concrete

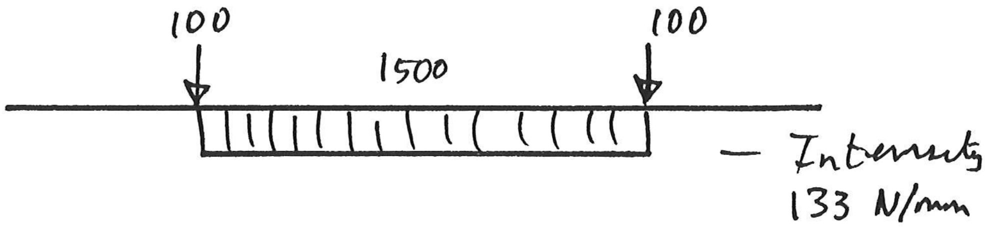
1. (a)

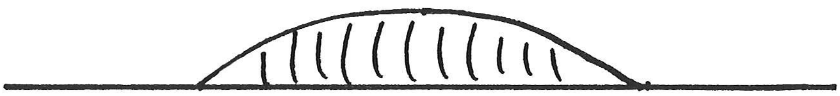




$$B.M = 143 \cdot \frac{350^2}{2} \quad (N, mm)$$

$$= \underline{8.750} \text{ KNm (sagging)}$$





$$B.M = \frac{wL^2}{8} = 133 \cdot \frac{1500^2}{8} \quad (N, mm)$$

$$= \underline{37.5 \text{ KNm}} \quad \text{(hogging)}$$

(b) Moment range at centre $= 37.5$ kNm

Z required $= \frac{37.5 \cdot 10^6}{20} = 1.88 \cdot 10^6 \text{ mm}^3$

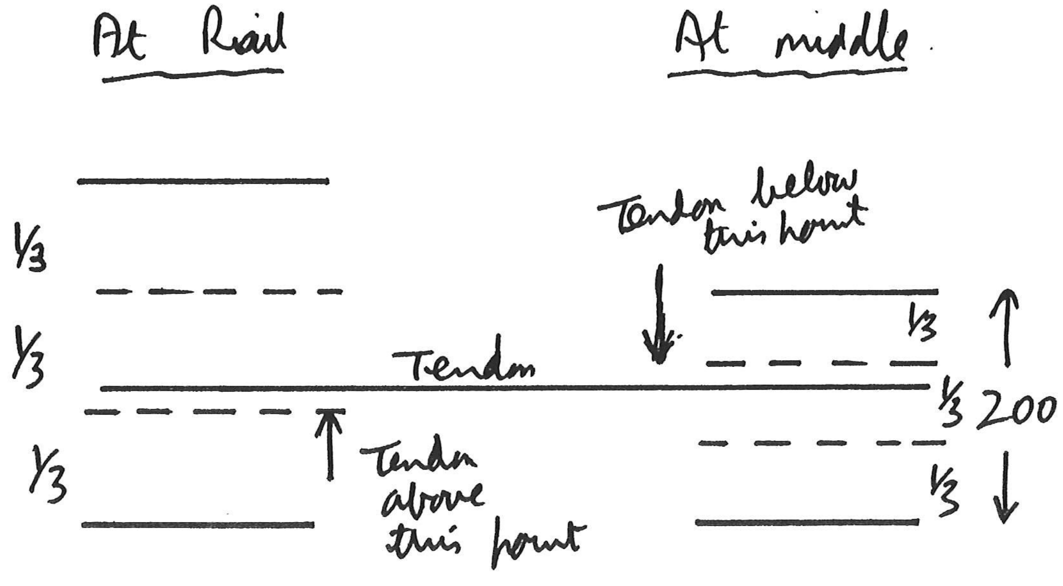
b fixed at 300 mm $\quad \therefore \frac{bd^2}{6} \geq 1.88 \cdot 10^6$

$\therefore d > 193$ mm

Choose $d = 200$ mm

(Candidates may choose different values but I expect them to perform similar steps.)

The tendon will need to be near the upper kern point at mid-span (since the moment is hogging) and near the lower kern point under the rail (where the moment is sagging).



Choose $d = 300$ at rail.

Tendon ≈ 130 mm above base.

(c)

	At rail	At centre
b	300 mm	300 mm
d	300 mm	200 mm
A	9.10^4 mm^2	6.10^4 mm^2
Z	$\pm 4.5.10^6$ mm^3	$\pm 2.10^6$ mm^3
Z/A	± 50 mm	± 33.3 mm

Choose a suitable prestress for drawing Magnel diag (not necessarily the final prestress)

$$= \frac{f_c}{2} . A_c = \frac{20}{2} . 300 . 200 = 600\text{kN}.$$

At mid-span: $e = -\frac{Z}{A} + \frac{\sigma Z}{P} + \frac{M}{P}$

moment range : $-37.5 \rightarrow 0$ kNm

When unloaded - comp at top $e \geq -33.3$ mm

tension at bottom $e \geq -33.3$ mm

When loaded. tension at top $e \leq -29.2$ mm

comp at bottom $e \leq -29.2$ mm.

At rail : Moment range $0 \rightarrow 8.75$ kNm

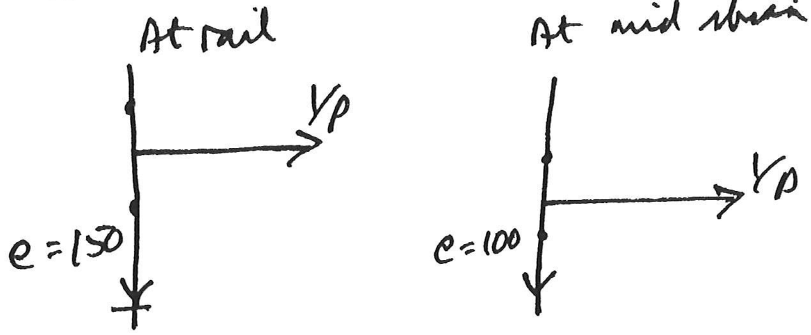
when loaded tension at bottom $e \geq -35.4$ mm

comp at top $e \geq -85.4$ mm

When unloaded tension at top $e \leq +50$ mm

comp at bottom $e \leq +100$ mm.

Draw two Magnel diagrams with eccentricity scales shifted so bottom edge of both sections coincide



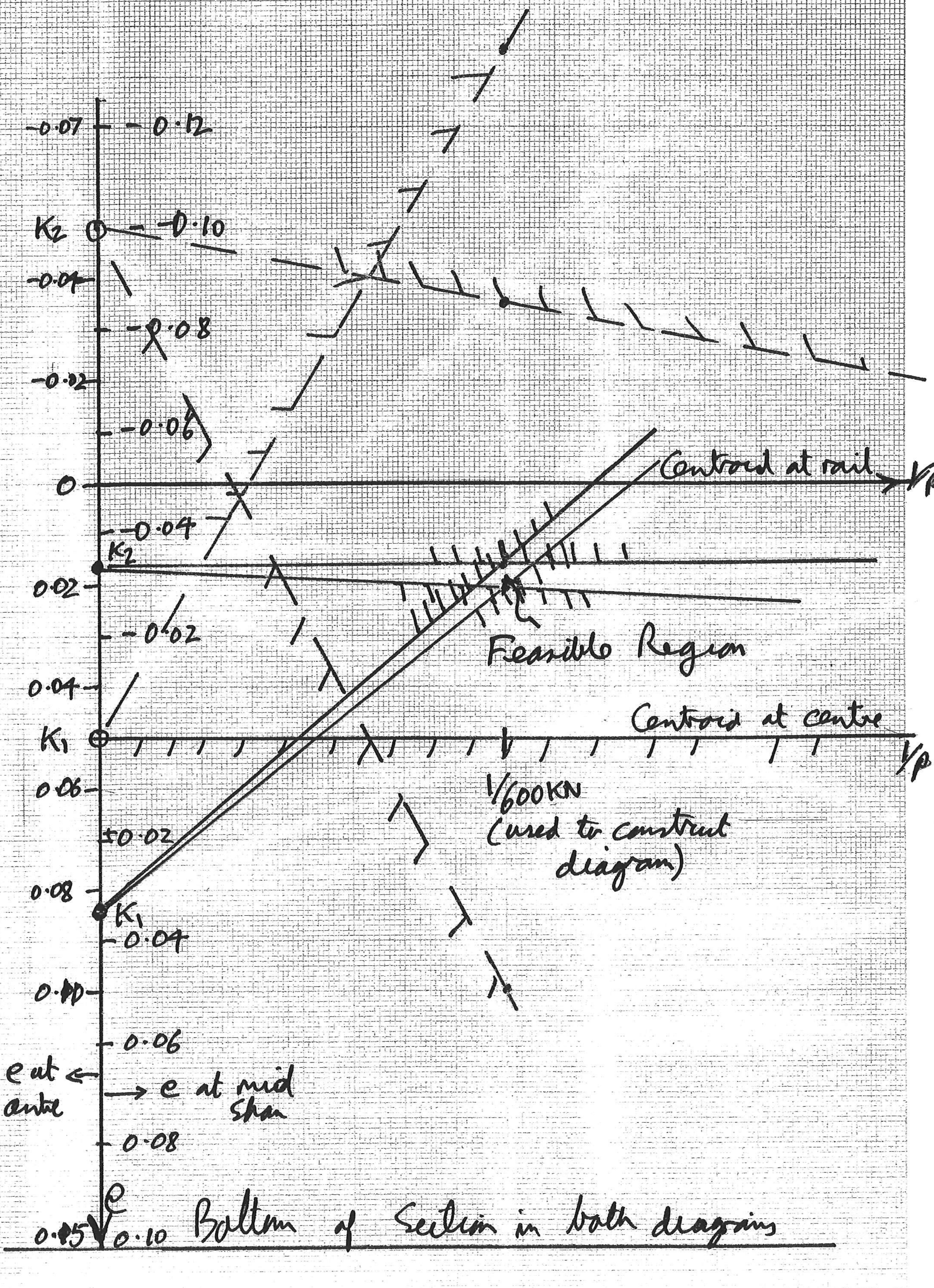
(see next sheet).

Behaviour at centre governs. For these values 600 KN is a suitable prestress at a height of about 132 mm above soffit.

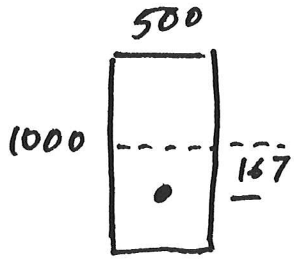
Assessor's comment:

Q1. Long question. Design of a railway sleeper. Most of the candidates could calculate the critical values of the bending moment, but some of their associated b.m. sketches were curious; they seemed to be fooled by the fact that there were no fixed supports. They were able to calculate the required dimensions and to draw a Magnel diagram for the two critical sections, but only three allowed for the fact that cable had to be in the same place for both locations. A few commented at the end that they should have done something different, but very few suggested what they might have changed.

Magnel diagrams at centre and mid-span



2.



$I = \frac{bd^3}{12} = 0.0417\ m^4$

$Z = .0833\ m^2$

$E = 30\ KN/mm^2$

$EI = 1.25.10^6\ KNm^2$

Self weight of concrete $= 0.5 . 23.6 = 11.8\ KN/m$

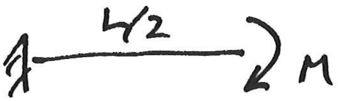
Deflection due to self weight $= \frac{5wL^4}{384EI}$ (databook)

$= 6.2\ mm$

Effect of prestress is to apply a uniform hogging moment

$M = Pe = 416.7\ KNm$

Data book



$\delta = \frac{M (L/2)^2}{2EI}$

$= 9.4\ mm$ (upwards)

∴ Net upward deflection $= 3.2\ mm$

State of stress after prestress is

Concrete will decompress when additional load causes a stress of 10 MPa.

$\therefore \frac{wL^2}{8Z} = 10 \Rightarrow w = 29.6\ KN/m$

(total load $= 41.4\ KN/m$)

Deflection due to this load $= 6.2 . \frac{29.6}{11.8} = 15.5\ mm.$

Concrete will crack when additional load causes stress of 14 MPa $\therefore w = 41.44$ kN/m
(total load = 53.2 kN/m)

Deflection due to this load = $6.2 \cdot \frac{41.44}{11.8} = 21.8$ mm

(these deflection measured from the value after prestressing).

Ultimate load. Yield strength of steel = 2500×1600
= 4000 kN

Cube strength of concrete = 60 MPa.

Average stress at failure = $0.6 \cdot 60 = 36$ MPa

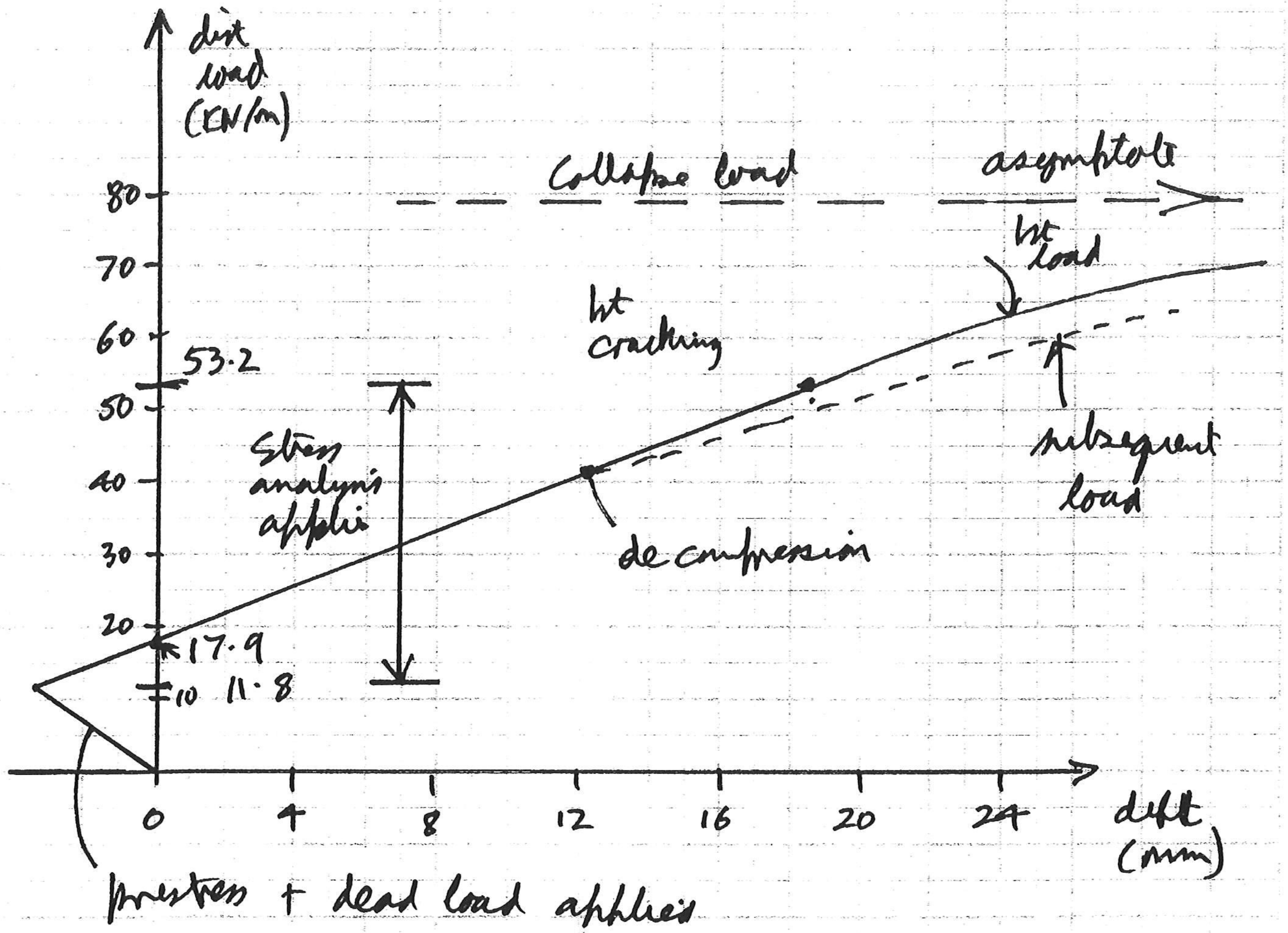
Area of compression zone = $x \cdot 500$ (x = depth of comp zone)

$\therefore x \cdot 500 \cdot 36 = 4000 \cdot 10^3 \Rightarrow x = 222$ mm.

$\therefore$ lever arm = $\frac{2}{3} \cdot 1000 - \frac{222}{2} = 555$ m.

$\therefore$ Moment capacity = $4000 \cdot 555 = 2220$ kNm

$\therefore \frac{wL^2}{8} = 2220 \Rightarrow w = 78.9$ kN/m.



Assessor's comment:

Q2. Long question. To produce an accurate load-deflection plot for a prestressed concrete beam. The ultimate load calculation was done reasonably well by most candidates, but some then tried to calculate the deflection at that load by an elastic calculation. However, the calculations for the upward deflection due to the prestress, and the initial elastic stiffness were not done well, despite this only involving simple data book calculations. Very few did what they were explicitly told to do, which was to plot to scale on graph paper.

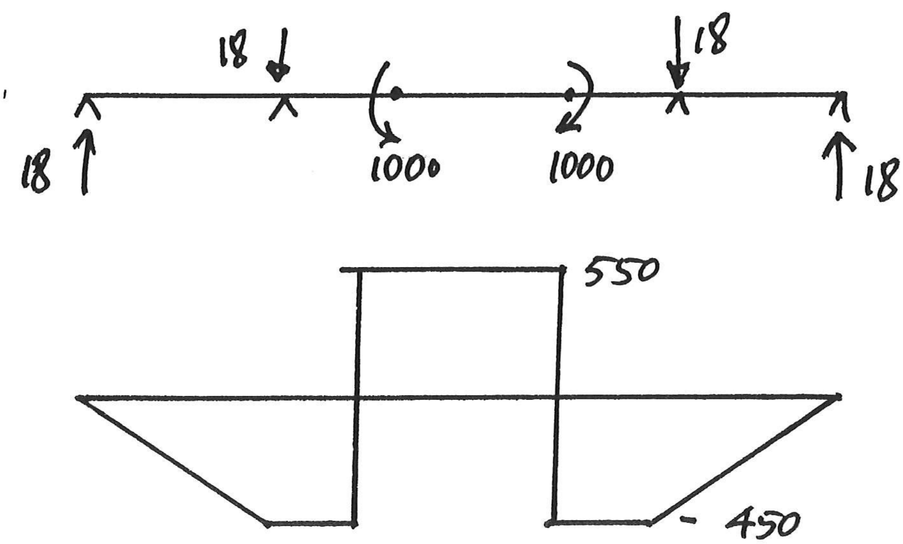
4D8/2010/~~2~~ 3/1

~~2~~ (a) The structure is statically determinate
3 under construction, so no secondary moments will be generated. Subsequently making the structure indeterminate will not affect that result.

(However, bonus marks if they point out that the effects of creep may mean that these moments may redistribute, and this <u>will</u> cause secondary moments, but much later).

(b) Determine moments induced by P_2

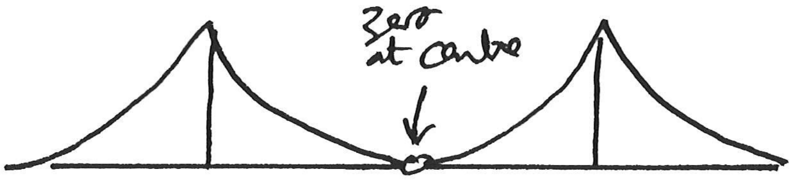
From Fig 2(b)



B.M.

∴ Secondary moment are:

(c) Dead load moments without M_2



But, with M_2

Adding this cable has reduced peak hogging moments and made ~~sagging~~ use of sagging moment capacity that would otherwise be unused.

Assessor's comment:

Q3. Short question. Calculation of secondary moments. Unpopular question, only attempted by a few students, but it was relatively easy because I provided them with enough information that they did not have to do an indeterminate analysis.

4 (a) Prestressed concrete needs more expensive steel than r.c, but less of it. It is expensive to bring ps equipment to site, but psc sections are usually thinner, so lighter, and allow longer spans.

(b) Prestressed concrete is almost always stiffer than r.c because it is uncracked.

(c) Not true. R.C is cracked giving easier access for water, CO_2 & O_2 to the steel, which leads to durability problems.

(d) The use of untensioned reinforcement can be incorporated relatively easily into the design process, but allowance does have to be made for the effects of creep, which significantly alters the amount of prestress that actually reaches the concrete because the untensioned reinforcement goes into compression.

Assessor's comment:

Q4. Short question. Four true/false questions that they were asked to justify. Popular and done reasonably well, although many students confused creep of concrete with durability.

5 (a) False. More flexible ducts mean more curvature due to flotation so more losses.

(b) False. No link between secondary moments & losses.

(c) False. Untensioned reinforcement does not affect losses due to friction

(d) False. Friction occurs before grouting.

(e) True. Untensioned reinforcement attracts compressive force so less available for concrete. (But tendon force much less affected)

(f) False. They cause a change in length of the tendon which has a bigger effect on short tendons.

(g) False. The tendons may be stressed before casting but the concrete is stressed later.

(h) ~~False~~ True. Post tensioned beams are usually older than pretensioned ∴ more mature ∴ higher modulus. ∴ Effect of change of length of tendon is greater.

Assessor's comment:

Q5. Short question. Eight true/false questions about losses of prestressing force, requiring only a single sentence of justification. Done by all candidates and done quite well, despite some of the answers needing quite subtle arguments. Only the last question, about relaxation losses in pre- and post-tensioned beams was done wrongly by a significant number of candidates.